Buffering capacity and acidification rates of cotton soils from northern NSW

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INTRODUCTION

Soils of high acidity are a major limitation to crop productivity in much of the world. In Australia acid soils covers about 40% of the total land area. Although soil acidification is a natural process but modern agriculture practices have accelerated acidification of soils compared with natural ecosystems in southern Australia (Bromfield *et al.*, 1983; Lewis *et al.*, 1987). Approximately 30 million hectares of acid soils have developed after land clearing since European settlement. Among various soil acidifying processes, leaching of nitrate produced by legume nitrogen fixation and from the application of ammonical fertilizers, and removal of bases in crop harvests, are the most important factors in increasing soil acidification rates in Australia.

Heavy clays, predominantly used for growing cotton in northern NSW, are generally alkaline and contain some free calcium carbonate in subsoil. Therefore, presently there appears to be no cause for concern from soil acidification in such soils. Other soils – particularly, lighter textured Red Earths and Red Brown Earths characterised by neutral or slightly acidic pH, are also used for cotton production. These soils may have a potential acidification problem.

Helyar *et al.* (1990) mapped the surface pH and estimated soil acidification rates for a number of agricultural systems in NSW. However, soil acidification rates for cotton soils are not known. This study was aimed to determine the buffering capacity of the cotton soils from three major valleys in northern NSW and to model soil acidification rates from these measurements. Such information will be useful in predicting potential soil acidification and in facilitating timely corrective measures by farmers and maintaining a sustainable cotton production system in Australia.

MATERIALS AND METHODS

For this research a total of 258 surface soil samples (0-10 cm depth) were taken from cotton growing regions of the lower Namoi, Macintyre and Gwydir Valleys in northern NSW. The sampling sites are shown in Figure 1. Grey, brown and black heavy alluvial clays are the dominant soils in these valleys. Red Brown Earths are common in Pilliga Scrubs in the southern part of the study area.

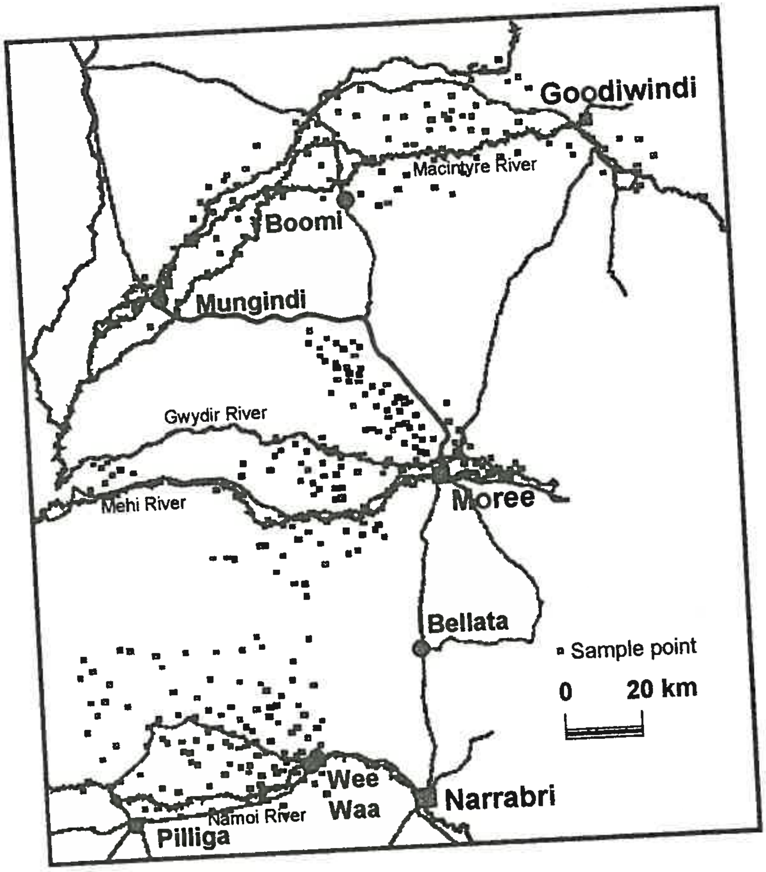


Figure 1. The map of north west of NSW showing the sampling sites.

Air-dried soils were ground to pass through 2 mm sieve for buffering capacity measurements and other analyses. Various physico-chemical properties, such as pH, electrical conductivity, organic carbon- and clay contents were determined using the procedures described by Rayment and Higginson (1992).

Two different techniques for determining buffering capacity- i.e. incubation and titration, were used to measure the pH buffering capacity (pHBC) of soils. The titration method was adopted from the procedure of Yuan and Lavkulich (1995). We weighed 5.0 g of oven-dry equivalent of air dry soil into a 100 ml polyethylene bottles and added 25 ml of 0.01 M $CaCl_2$. The bottles were placed on an end-over-end shaker for 30 minutes and at the end of the shaking period the pH was measured. Then to each bottle 2 ml of 0.01 M HCl was added. After the addition of acid, the bottles were allowed to shake for at least two hours and the pH of the suspension was measured again. Incremental addition of acid followed by 2 hr equilibration and pH measurements, were continued until pH ≈ 5 was obtained and the total volume of acid added to achieve this pH value was recorded.

The incubation method was adopted following the procedure outlined by Tran and van Lierop (1982). We used 40 g of oven-dry, equivalent of air dry soil. The sample was thinly spread over a plastic sheet and approximately 10 ml of 0.2 M HCl was added by using a spray bottle, and constantly mixing the soil after each spray. The exact volume of 0.2 M HCl added was determined by weighing each soil sample after spraying. The volume of acid added to each sample was based on the buffering capacity values obtained by the titration method. The samples were brought to field capacity by adding deionised water and maintained at this moisture level for 4 months at a constant temperature of 23±2°C. After this period, the samples were dried at 40°C and pH was measured in 1:5 soil solution ration in 0.01 M $CaCl_2$.

For each method, pHBC was calculated as follows:

$$\text{pHBC (cmol/kg/pH unit)} = \frac{\text{Centimoles of } H^+ \text{ consumed}}{\text{Mass of oven dry soil (kg)} \times \Delta\text{pH}}$$

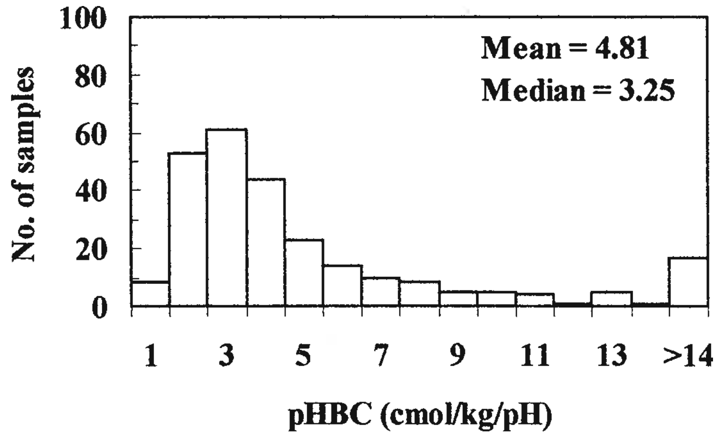
where ΔpH is the difference in the initial pH and the final pH after the addition of HCl.

RESULTS AND DISCUSSION

The pH Buffering Capacity of soils: The pH buffering capacity values were quite similar for the two methods with mean values of 4.81 cmol/kg/pH and 5.19 cmol/kg/pH for the titration and the incubation methods, respectively (Figure 2a,b). The pHBC values obtained for the samples are similar to values reported by Helyar *et al.* (1990) for clayey soils. There was a strong correlation (r = 0.76) between the pH buffering capacity obtained by the two methods. The pHBC values are slightly lower for the titration method than the incubation method, which indicates that equilibrium was not reached during the 2 hr shaking period used after each increment addition of acid.

There was no significant correlation between soil properties, such as pH, organic carbon and clay content, and pHBC of soils for both the methods (Fig. 3). This is probably due to the fact that calcium carbonate is the main buffering agent in these soils.

(a)



(b)

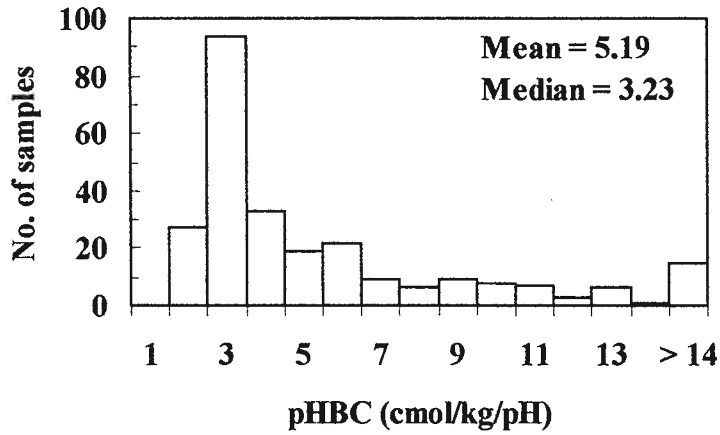


Figure 2: Histograms showing the distribution of pHBC by (a) titration and (b) incubation methods.

Soil organic matter has been reported to play the most significant role in influencing soil pHBC (Magdott and Bartlett, 1985). The soil samples used in this study contain relatively low organic carbon (Mean OC = 0.86%) and in the presence of $CaCO_3$ may have a little influence on the pHBC of soils.

Estimation of Soil Acidification Rates: Soil acidification rates of the soils were estimated based on the assumption that acid input was 5 kmol/ha/year and the absorption of the acid by the surface soil is 28% (Heylar *et al.*, 1990). The predictions made from the incubation pHBC values indicate that it would take between 10 to over

400 years for soil pH to decrease by one unit. In 90% of the soils pH will drop by one unit within 100 yr and in 10% of the samples this will happen within 15 years.

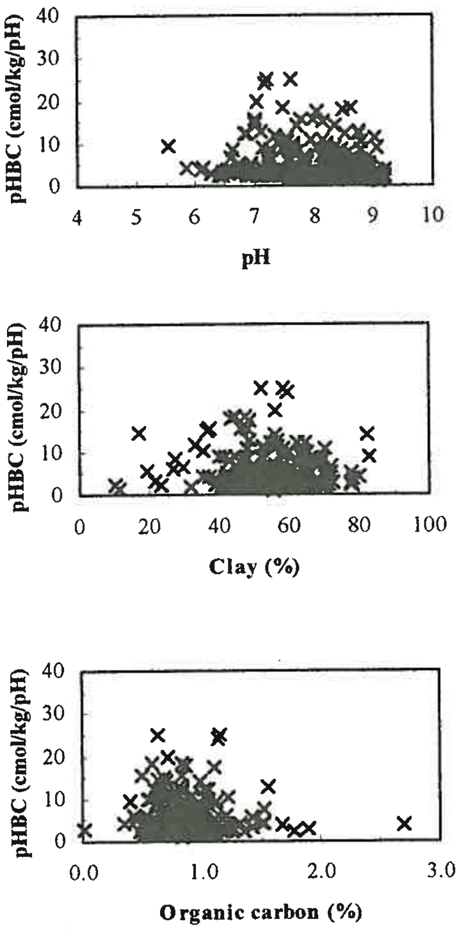


Figure 3: The relationshipe between pHBC (cmol/kg/pH unit) by incubation method method with soil pH, organic carbon and clay content.

The distribution pattern of the current soil pH in the study region is shown in Figure 4a. The soil pH values increase from east to west, ranging from about 6.5 to just over 8.5. The trend in pH is not surprising, as there is probably climatic influence on the acidification process, which is less intense as we move towards the west. As the average annual rainfall decreases towards the west the pH values increase probably due to accumulation of bases, and more so, carbonate and bicarbonate in the soil profile.

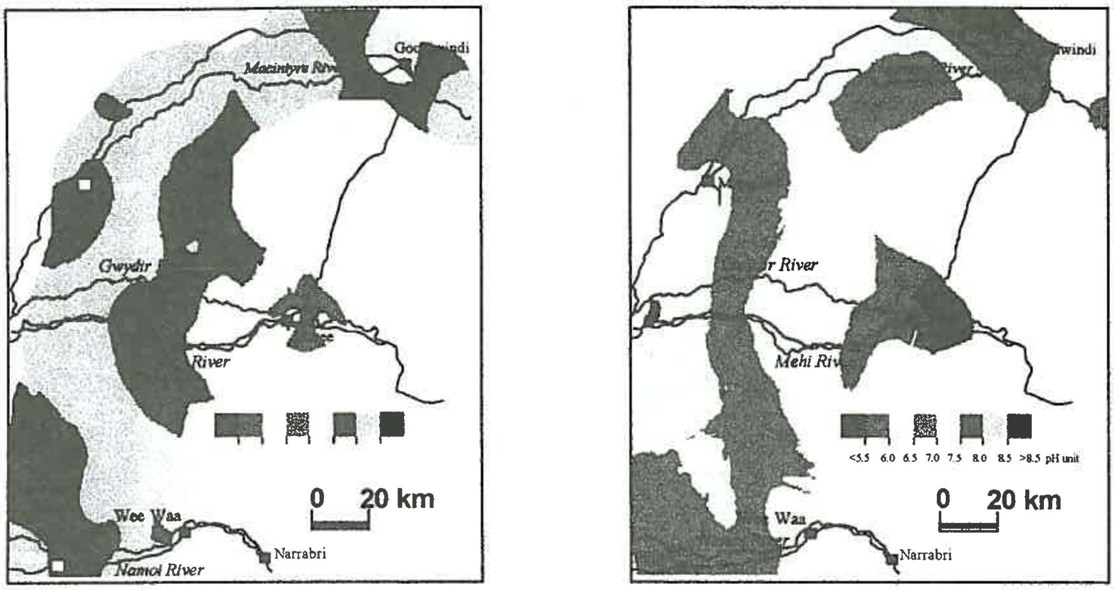


Figure 4. a) Present day topsoil pH **b) Predicted topsoil pH in 50 years from present.**

Figure 4b shows the distribution pattern of soil pH in 50 years from present, as predicted using pHBC equation above. The areas shown in red and brown near Goodiwindi and Moree are likely to become acidic first. In a hundred years, most of the eastern part of the region would become intolerably acidic. This highlights the possible problems in the near future in respect to soil acidity and the need to re-examine the current agronomic practices that may ameliorate the problem. Once soil pH decrease below 5.5, i.e. under moderately acidic soil conditions, cotton plants may be susceptible to Al and Mn toxicity. Since cotton is a sensitive crop to acidic soil conditions, the low pHBC soils will probably lead to acidity problem within a short time as indicated above. The projections provided in this paper, even though very broad, provides a good overview of present situation for cotton soils in NSW.

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